GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

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OAM

Date: February 17, 1978

Project Title: Radar Reflectivity of Airborne Insects

Project No: B-501

Project Director: Mr. E. F. Greneker

Sponsor: U. S. Dept. of Agriculture; Western Cotton Research Laboratory; Phoenix, Ariz. 85040

Agreement Period: From 1/6/78 (1/6/78) Until Approx. four (4) month after work begins.

Type Agreement: Verbal confirmation of USDA/WCRL letter dated 11/21/77 referencing USDA South Reg. Coop. Agree. No. 12-14-7001-60 w/GIT.

Amount:

$5,000 USDA Funds
3,328 GIT Contrib. (E-702-804)
$8,328 Total

Reports Required:

Monthly Progress Letters; Final Report.

Sponsor Contact Person (s):

Technical Matters

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Contractual Matters
(thru OCA)

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Procurement Office
Phone: 602-261-3714

U. S. Department of Agriculture
Western Cotton Research Laboratory
4135 E. Broadway Road
Phoenix, Ariz. 85040

Defense Priority Rating:

Assigned to: Radar Instrumentation Laboratory (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
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- Project Code (GTRI)
- Other

CA—3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Posted 10/6

Date: 9/25/78

Project Title: Radar Reflectivity of Airborne Insects

Project No: B-501

Project Director: Mr. E. F. Greneker

Sponsor: US Dept. of Agriculture; Western Cotton Research Laboratory; Phoenix, Ariz. 8504(

Effective Termination Date: 9/13/78(Final Report submitted)

Clearance of Accounting Charges: by 9/30/78

Grant/Contract Closeout Actions Remaining:

- x Final Invoice and ~~Closing Documents~~ Final Fiscal Accounting
- _ Final Fiscal Report
- _ Final Report of Inventions
- x Govt. Property Inventory & Related Certificate (if applicable - title vests w/Gov't.)
- _ Classified Material Certificate
- _ Other _____

Assigned to: Radar Instrumentation Laboratory (School/Laboratory)

COPIES TO:

Project Director
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Project File (OCA)
Project Code (GTRI)
Other _____

CA—4 (3/76)

B-501

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

6 February 1978

Western Cotton Research Laboratory
4135 E. Broadway Road
Phoenix, AZ 85040

Attention: Mr. W. W. Wolf
Project Monitor

Subject: Research and Development Status Report No. 1, USDA/Georgia Tech Project B-501
"Radar Reflectivity of Airborne Insects"
Status Report Covering the Period 15 January 1978 through 31 January 1978

Gentlemen:

The literature search on Project B-501 began January 15, 1978. A master reference compilation is being developed. All sources found and thought to pertain to insect measurements are being included. In addition Georgia Tech generated classified and non-classified bibliographies on radar cross section measurements have been reviewed for insect measurement data. A master list of approximately 150 references taken from all sources that may be pertinent to the project have been developed from the two original bodies of data. Presently work is continuing to locate this material in the Georgia Tech library. Each source investigated will be ranked in three categories. The pertinence of subject matter will be determined from these rankings.

A computerized literature search of non-classified data bases has also been undertaken. It is hoped that this phase of the search will uncover additional sources that have been generated in the recent past. Numerous key words pertaining to insect radar studies were used in this computerized search. Output from this phase of work should become available during February.

Future Work

Ways are being investigated to allow access of pertinent titles within the classified body of radar study data known to exist.

Respectfully submitted,

E. F. Greneker
B-501 Project Director

Approved:

J. D. Echard, Chief
Radar Analysis Division

cc: E. K. Reedy, J. L. Eaves, J. D. Echard

B-501

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

March 10, 1978

Western Cotton Research Laboratory
4135 E. Broadway Road
Phoenix, AZ 85040

Attn: Mr. W. W. Wolfe
Project Monitor

Subect: Research and Development Status Report No. 2, USDA/Georgia Tech Project B-501, "Radar Reflectivity of Airborne Insects." Status report covering the period 1 February through 28 February 1978.

Gentlemen:

The search phase of the literature search undertaken January 15th 1978 is partially completed. Georgia Tech is presently pursuing the obtainment of microfiche and hard copies of the work thought to be pertinent as a result of findings during the search phase.

To date the search has included titles catalogued within the NTIS, NASA and DOD literature search system. Over 60 reports and documents found during this search have already been reviewed for pertinence. A small percentage of these works are found to include references to actual radar cross-section measurements made on selected insects. A large percentage are found to mention insects as radar "clutter" or anomalies. This second class of reference fails to provide quantitative data concerning relative radar cross section.

A better estimate of the number of pertinent references should be available after the March work has been performed. The remainder of March will be devoted to the location of additional hard copy and microfiche copies of the titles developed thus far.

Respectfully submitted,

Gene Greneker, B-501
Project Director

Approved by:

J. D. Echard, Chief
Radar Analysis Division

B 501

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

April 5, 1978

Western Cotton Research Laboratory
4135 E. Broadway Road
Phoenix, AZ 85040

Attention: Mr. W. W. Wolfe
Project Monitor

Subject: Research and Development Status report No. 3, USDA/Georgia Tech Project B-501, "Radar Reflectivity of Airborne Insects". Status report covering period 1 March through 31 March, 1978.

Gentlemen:

The search for references relating to reflectivity measurements of airborne insects at microwave frequencies has been concluded. During the month of March the references found to date were organized and an index is being finalized. An appendix containing copies of the reference articles, the index and a brief report summarizing Georgia Tech's search methods and general findings will constitute the final product of this research project.

To date, approximately 190 articles have been identified as possibly being pertinent to the research subject. Of this total, approximately 110 of these articles have been located and reside in the form of micro-fische or xerox copies as part of the project file. Approximately 70 of the on-hand references pertain to the subject of detection of insects with radar. The remainder deal with various atmospheric effects that could affect the success of future radar insect programs. Approximately 35 of the total references located to date actually discuss insect/microwave backscatter measurements. It is estimated that 10 - 15 of these references deal with original measurements; the remainder being re-hash type reviews of the previously performed measurements.

The classified literature has been consulted on the subject of insect measurements. Georgia Tech personnel are still in the process of locating all of these references. Two classified references have been located thus far. They pertain to insect measurements that have also

been reported by the original author in the open literature.

Respectfully submitted,

E. F. Greneker
Project Director

EFG:nsb

Approved:

J. D. Echard
Radar Analysis Division Chief

B-501

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

5 May 1978

Western Cotton Research Laboratory
4135 East Broadway Road
Phoenix, Arizona 85040

Attention: Mr. W. W. Wolfe, Project Monitor

Subject: Research and Development Status Report No. 4
USDA/Georgia Tech Project B-501, "Radar Reflectivity of Airborne Insects". Status Report Covering Period 1 April through 30 April 1978.

Gentlemen:

A majority of the hard copy and microfiche copies of the references (identified during March) pertaining to insect measurements were located by April 30th. These references were read and sorted.

A table was prepared on the references that specifically mentioned insects measurement by radar. The extent to which the measurements pertain to useful insect measurements was developed in a one paragraph summary on each article in the table. References that included quantifiable measurements were treated in an expanded manner. The measurements results were listed as were the basic measurement frequencies, techniques, etc.

This information was prepared in draft form for discussion with USDA personnel attending the USDA/NASA workshop on radar measurement of insects held at Wallops Island, May 2-5. A final report on the project will be prepared during the month of May.

Respectfully submitted,

E. F. Greneker
Project Director

Approved:

J. D. Echard, Chief
Radar Analysis Division

cc: J. D. Echard, J. L. Eaves, E. K. Reedy

RADAR REFLECTIVITY OF AIRBORNE INSECTS
A LITERATURE SURVEY

By

E. F. Greneker and M. A. Corbin

Prepared for

Western Cotton Research Laboratory
United States Department of Agriculture
Phoenix, Arizona

Cooperative Agreement No. 12–14–7001–60

June 1, 1978

Prepared by

Radar Analysis Division
Radar and Instrumentation Laboratory

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA 30332

1978

Radar Reflectivity of Airborne Insects

A Literature Survey

By

E. F. Greneker

and

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Prepared For:

Western Cotton Research Laboratory

United States Department of Agriculture

Phoenix, Arizona

Cooperative Agreement No. 12-14-7001-60

June 1, 1978

Prepared by:

Radar Analysis Division

Radar and Instrumentation Laboratory

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30033

Foreward

This literature survey was undertaken as a jointly funded effort between the U. S. Department of Agricultures's Western Cotton Research Laboratory and the Radar and Instrumentation Laboratory. The research program was conducted within the Radar Analysis Division under Georgia Tech cost sharing Project B-501 with E. F. Greneker, Research Scientist, serving as Project Director. This work covers tasks performed between January 15, 1978 and May 30, 1978.

Respectfully submitted,

E. F. Greneker
Project Director

Approved:

_____

J. L. Eaves, Associate Director
Radar & Instrumentation Laboratory

ACKNOWLEDGMENTS

The authors would like to thank Mr. Wayne W. Wolf, U.S.D.A. Project Monitor, for his advice and guidance during this report's preparation. We would also like to acknowledge the contribution made by Dr. Waldemar Klassen, U.S.D.A., Washington, and Mr. J. J. Teti, Dahlgren Laboratory, N.S.W.C., Dahlgren, Virginia. We would like to thank co-op student R. V. Folea for his help in the technical preparation of selected figures and tables within this report.

TABLE OF CONTENTS

SECTION I

INTRODUCTION

Before advanced insect control techniques can be used successfully, characteristics concerning the insects' dispersal behavior must be known. This dispersal behavior often results in new infestations or expanded populations and must be compensated for by pest management programs. The ground level meteorological conditions which influence dispersive flight and the upper air conditions which transport or concentrate the insects must be determined.

Radar has been used as one tool to study the dispersal phase of a limited number of insects. Most of the applied radar entomological work done to date has been conducted by British scientists on African locusts and spruce budworms.

One of the first known instances of radar being used as an entomological tool occurred in 1954[1]. The use of radar in this instance allowed entomologists to determine that (yellow) desert locusts could maintain swarm cohesion in darkness. During the 24 years that have followed other radar measurements have been made on insects in swarms and individual insects in free flight. Radar measurements were also made in the laboratory environment

on "pest" insects under carefully controlled conditions. In 1974[2] members of the British radar entomology community were predicting that radar equipped aircraft could be used to locate certain airborne "pest" insects, especially when they are concentrated by converging wind systems. Airborne spraying operations could then be used against the airborne insects using pesticides or behavior confusing chemicals.

The U. S. Department of Agriculture recently began a radar entomology program at the Western Cotton Research Laboratory, Phoenix, Arizona. This program, under the direction of W. W. Wolf, Agricultural Engineer, will determine what contributions radar sensors can provide in understanding the dispersal habits of selected pest insects common to the United States. Georgia Institute of Technology was requested to assist in this effort by utilizing the expertise of the personnel and equipment in the Radar Analysis Division, Radar and Instrumentation Laboratory of the Engineering Experiment Station.

The first step in defining the direction that the United States radar entomological program should take was to determine what research has been done in the broad area of radar/insect studies. This first task was defined as a literature review. The remainder of this report is devoted to presenting a brief review of the pertinent literature that was located during this study. A complete listing of both pertinent and non-pertinent titles located during the search is presented in the Master Index in Appendix I.

A. The History and the Literature of Radar Studies of Airborne Insects

Historically there have been 3 main areas of scientific study concerning radar observation of insects. The topic areas of these past

studies include radar entomology, meteorological radar investigations and military research. Contributions were made to the body of radar entomology knowledge through the work done in each of these three areas.

The British, having pioneered the use of radar as an entomological tool in 1954[3], have continued to use radar in various insect pest mangement projects. This past work has included the measurement of locust radar cross sections made by Riley (1973)[4] in the laboratory and field measurements described by Riley (1974)[5]; Schaefer (1970)[6]; Schaefer (1976)[7] and others. Both U. S. and British researchers have measured the sensitivity of the radar cross section of locusts to a change in the polarization of the transmitted signal. Hajovsky, Deam and LaGrone (1966)[8] first made laboratory polarization measurements in the United States. Later Riley (1975)[9] used the change in locust cross section as a function of polarization to imply insect orientation with respect to the ambient wind field.

Many of the radar entomologists conducting field measurement programs used Decca Marine Radars with a pencil beam antenna as the basic sensor system. The radar and antenna were van-mounted for portability. Even though rather basic equipment was employed (by today's standards) they have been able to discover previously unknown facts concerning the nocturnal flight characteristics of selected insects.

Radar observations of airborne insects were made by radar meteorologists as part of a much larger program to study radar returns from "the clear atmosphere". During the mid-1960's extremely sensitive radars were developed as a joint project between the U. S. Airforce and the National Aeronautics and Space Administration (NASA). The system was appropriately called the JAFNA radar system and it was constructed at Wallops Island, Va.

The extremely high sensitivity of the system (compared to other radars of the period) allowed radar returns from the optically clear atmosphere to be detected.

Numerous unexplained "dot angel" targets were detected during these studies. Glover (1965)[10], Hardy (1969)[11], Konrad (1968)[12], and others used the JAFNA system to measure the general characteristics of the then unexplained "dot angel" echoes. Several of these investigators were able to link the unexplained "dot angel" echoes to the presence of insects. This linkage was made by comparing the results of radar cross section measurements of known insects made under controlled laboratory conditions to the cross section data obtained during "clear atmosphere" probes. The correlations established between these two sources of data led researchers to conclude that insects were responsible for many of the "clear atmosphere" radar returns.

Doppler measurements of "dot angel" echoes showed that atmospheric anomalies also contributed to their presence. It was during the clear atmosphere probes that Glover, et al (1966)[13] made the first radar cross section and flight characteristic measurements on single insects under free flight conditions.

The Department of Defense became interested in the radar signature of insects when the Hostile Weapons Location System (HOWLS) technology was perfected to the point where targets with extremely small radar cross sections could be detected by radar at medium ranges. These investigations grew out of the fact that numerous targets appeared on the HOWLS radars when no targets were observed optically in the volume of space scanned by the antenna. These "clear air" (Angel) targets were eventually linked to the presence of birds and insects in the HOWLS operating environment.

Several source documents pertaining to HOWLS studies are classified. However, most of the data pertaining to insect studies have been extracted from the classified literature, "sanitized" and then published in the open literature. References by Downing and Frost (1972)[14]; Fishbein, Frost and Vander Meer (1970)[15]; Frost (1972)[16]; Frost (1970)[17], Frost and Robinson (1973)[18], Reedy and Cutler (1975)[19]; and Tarbell (1972)[20] all belong to this later category. Thus, there was no need to list classified documents in this report (classified documents were reviewed to make this determination).

Given this 24 year history of radar entomology, numerous papers and articles have been published concerning the subject of radar entomology in scholarly journals, symposiums, and the mass media. In an attempt to locate many of these past publications, RAD project personnel searched most of these sources during the search phase of the research program.

B. The Literature Search

The process used in the literature search is discussed in Section II, and thus will not be covered extensively at this point. The logic that determined the search technique was relatively "straight forward". It was initially assumed that the pertinent literature would be found in the journals and official publications of at least 4 scientific disciplines: (1) entomology; (2) biological sciences; (3) radar meteorology; (4) defense project engineering (the latter discipline requiring that the classified literature be searched).

The literature search procedures outlined in Section II were followed, and as a result two basic bodies of literature were produced. A large body of located literature pertained to radar observation of targets thought to be insects or atmospheric effects. A major portion of these references did

not specifically identify insects as the source of the radar returns other than to briefly mention "insects" as a possible source. These types of references, while interesting, were not considered for presentation except for inclusion in the Master index and the Master reference library files. The second and much smaller group of references pertained directly to research relating to radar observations of insects. These references included the quantitative and qualitative results presented in the remainder of this report.

C. Search Results

Figure 1 was developed to show the number of publications that were located as a function of the publication date of each reference. The histogram in Figure 1 shows the number and distribution of all the publications appearing in the Master index and thought to contain useful data. The entomological, weather radar, and Department of Defense literature are all lumped in this group of references. A pronounced peak in the number of publications exists in Figure 1 for the year 1966. Close analysis shows that most of these references were generated as a result of investigators reporting the results of "clear air" probing with the (then new) JAFNA radar and other sensitive radar systems.

Figure 2 was generated to show the number of references reviewed and thought to be of primary interest to the entomological radar community plotted as a function of publication date. These references were selected on the basis of five criteria. In order to qualify as a "basic" type reference the work had to meet one of the following criteria as a minimum:

(1) contain basic radar cross section measurement of known insects;

(2) contain backscatter measurements on radar targets thought to be insects;

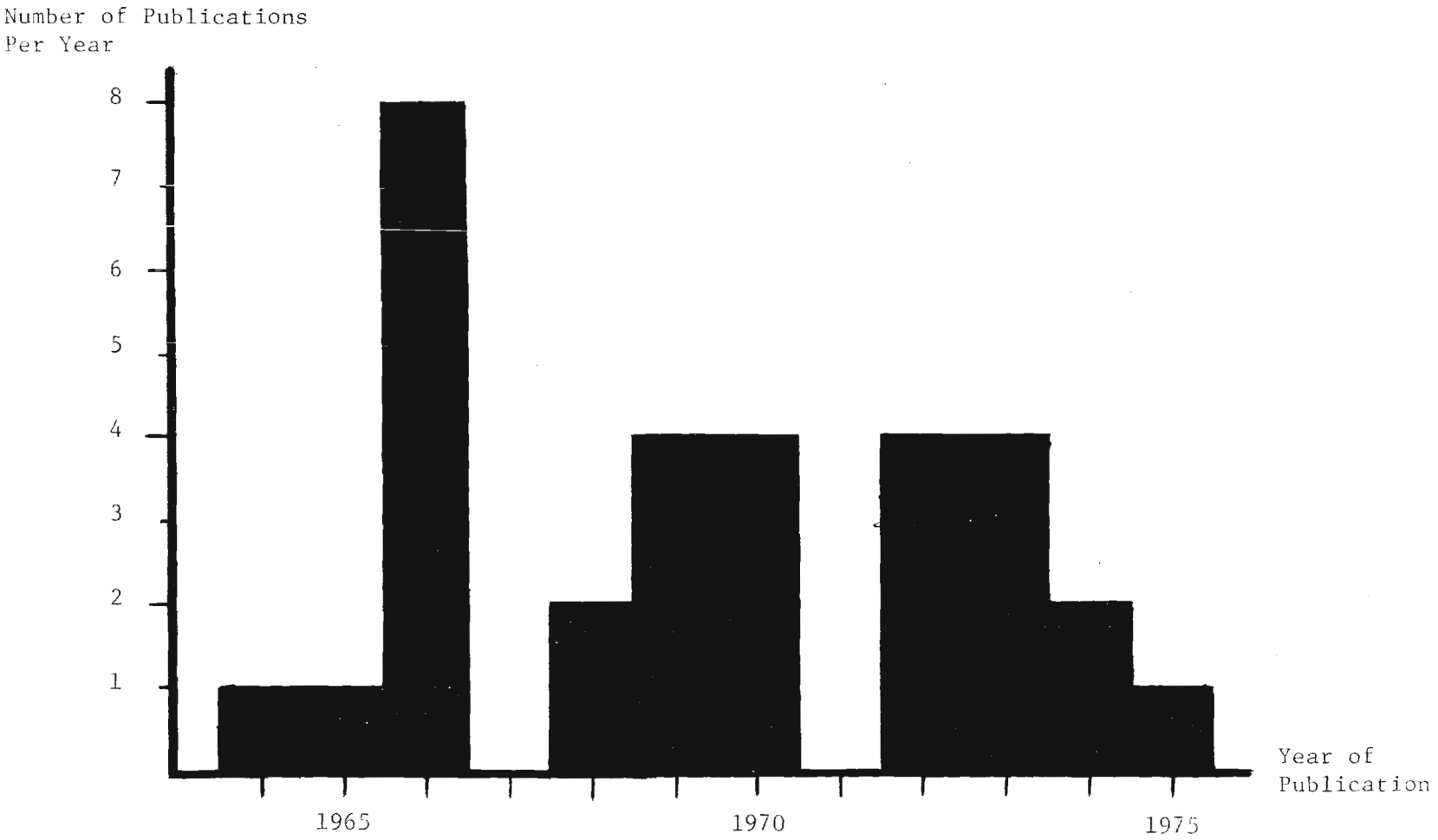

Figure 2. Histogram showing the number of references plotted as a function of Publication date, that are thought to be of special interest to the radar entomological community.

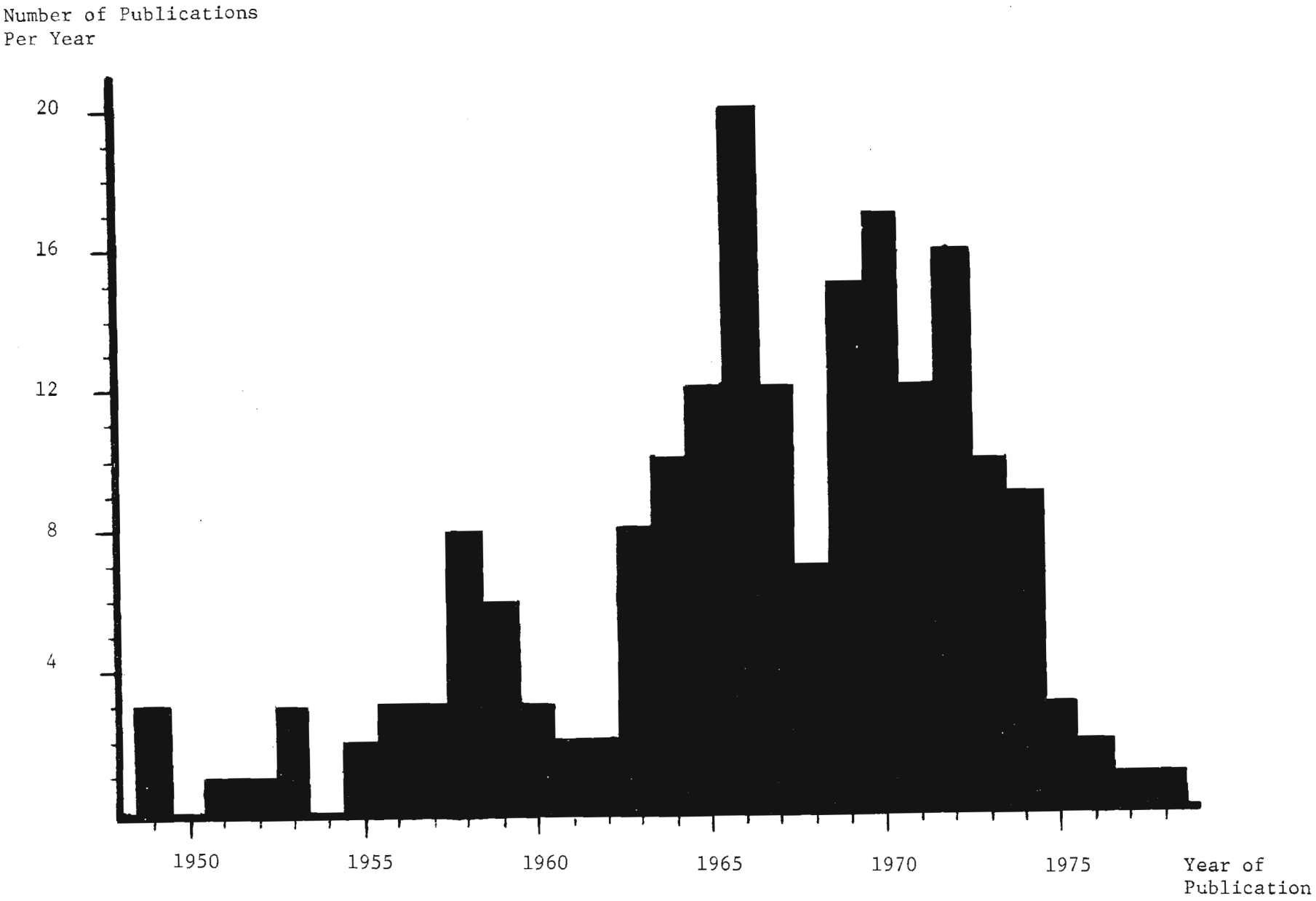

Figure 1. Histogram showing the number of "all type" radar/insect references found plotted as numbers versus year of publication.

(3) contain a summary of other work pertaining to measurements; (4) explain certain phenomenon thought basic to future radar entomological research or (5) discuss radar entomological programs.

D. Tabular "Quick Reference" Data

The references in Figure 2 were reviewed and each was found to meet at least one of the five aforementioned criteria. Thus, each of the references in Figure 2 was evaluated as pertinent literature and was reviewed closely. Certain data were extracted from each source. Table I was generated to provide a "quick reference" to this data.

Referring to Table I, the first column contains the reference number that corresponds to the full title in the Master index. Column 2 contains the first author's name. Column 3 contains the date of publication. Column 4 contains a brief synopsis of the work referenced. If actual measurements were made or referenced by the author, then the wavelengths(s) at which the measurements were made is shown in Column 5. In many cases (early clear-air probe studies) the types of insects being observed by radar was unknown. If the observed or measured insect is "known", the "type" of insect is shown in Column 6. When the resulting measured radar cross section is referenced for a known or unknown insect target, the cross section (referenced to 1 square centimeter) is presented in Column 7. In several cases the units in the original reference were not in the required units and required conversion to units of square centimeters. If the measurement radar type (name) and characteristics were given, then this information is shown in Column 8. The range resolution of the measurement radar is shown in Column 9. If data was deleted in Table I, it was either not available from the source reference, not applicable, repeated elsewhere or presented in another reference.

Table I

Quick Reference Literature Guide

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
A-11	Atlas	1966	This investigation was undertaken in an attempt to identify the source of "angel" echoes. The author(s) never actually observed the source of the clear air (angel) returns that were thought to be insects. The author(s) rely on measurements made by others to infer that the source of these "angel" echoes are insects. No original insect measurements are presented, but the review of insect measurements was thought to be of value.	-	-	-	-	-
A-14	Atlas	1970	The investigation described in this paper was undertaken to show that the speed of "dot angels" and other targets could be measured using a fixed Pointing Gaussian circular radar beam. Speed is determined by analyzing the amplitude fluctuations in the return signal as the target crosses the beam. The observed "dot angels" are inferred to be insects on the basis of their cross section and speed.	10 cm	UNKNOWN	Cross Section range from $2.11 \times 10^{-3} cm^2$ to $9.84 \times 10^{-5} cm^2$	FM/CW radar located at NELC San Diego, Cal.	1 meter
A-16	Atlas	1969	The author(s) are primarily reporting findings on atmospheric effects related to clear air turbulence studies. The "dot angels" observed	10 cm	UNKNOWN	Various	FM/CW radar located at NELC San Diego, Cal.	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
A-16 (cont.)			are thought to be insects. The "dot angels" are used as tracers to imply the location of various atmospheric layers.					
B-1	Barry	1973	The author treats angel echoes as clutter that may be encountered in the operation of an air traffic control radar. No original measurements are discussed or presented. This work was included because a table showing comparative cross sections between aircraft, birds, and insects is presented (p. 58). This table contains data extracted from other sources.	-	-	-	-	UNKNOWN
B-3	Battan	1973	This reference is Chapter 12 of Battan's text on radar meteorology. Numerous sources on radar measurements of insect cross sections are referenced. Battan cites results of his own research concerning polarization characteristics of "angel" echoes (thought to be insects).	3 cm	UNKNOWN	From $8 \times 10^{-5} cm^2$ to $1.3 \times 10^{-1} cm^2$	Bistatic vertical pointing dual polarized system	UNKNOWN
B-15	Browning	1966	This investigation was undertaken to measure the velocity characteristics of the clear air "dot angel" phenomena using pulsed Doppler radar. Insects were assumed to be the	5.42 cm	UNKNOWN	$10^{-4} cm^2$ to $2 \times 10^{-1} cm^2$	Pulse Doppler "Porcupine" radar at AFCRL (now AFGL)	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
B-15 (cont.)			primary targets observed. The insects were not identified. The "angel" targets were classified into three (3) basic types on the basis of their velocity.					
B-17	Brylev	1970	The author investigated the radar reflectivity characteristics of a "clear sky". The original work is in Russian and was translated by the U.S. Army Foreign Science and Technology Center. Insect measurements done by American authors are cited. The source of the observed "angel" echoes is not determined.	-	-	-	-	-
C-4	Chernikov	1965	The section of this reference that pertains to insect measurements is not original work by the author. The report is translated from Russian. It cites insect measurements by Russian and U.S. Scientists. The purpose of the report was to explain sources of clear air echoes through a survey of existing U.S. and Russian literature. Various U.S. authors conducting radar "angel" research are cited in this reference.	-	-	-	-	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
D-5	Downing/ Frost	1972	This reference was taken from the proceedings of the Fifty-ninth Annual Meeting of the New Jersey Mosquito Extermination Association. The data presented was taken by the authors. Observed data is more qualitative than quantitative. The work in reference T-1 is also cited.	1.8 cm	(Diptera culicidae)	Various depending on aspect angle.	HOWL's radar Fort Monmouth, New Jersey AN/MPQ-4	37.5 m
F-2	Fishbein	1970	Classified, but sanitized and appearing elsewhere.	-	-	-	-	-
F-4	Fishbein	1969-70	The author(s) used two radars to observe clear air echoes. B-scope and Doppler spectrum photographs are presented showing signatures from birds and other sources. Insect and bird cross section data taken from other references are presented as supporting data.	-	-	-	-	-
F-8	Fowler	1969	The author(s) speculate on the value of using polarization characteristics of insects to develop techniques that would allow radar operators to discriminate between "angel" echoes from insects and those caused by other atmospheric effects. This reference cites numerous other sources	-	-	-	-	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
F-8 (cont.)			on the dynamics of insect flight. Investigators attempting future work in the field of radar insect measurements should have a copy of this reference. The conclusions drawn by Fowler and La Grone in this reference may be premature given the finding in R-20 and other references dealing with polarization effects (Ga. Tech authors opinion).					
G-5	Glover	1966	The author(s) discuss radar cross section measurements taken at three frequencies simultaneously on angel echoes. It is implied that these echoes are insects and birds. The work done by other investigators to identify various insects and catalogue their cross section is presented.	3.2, 10.1 and 71.5 cm	UNKNOWN	Various	JAFNA radar Wallops Island, Virginia	Various
G-7	Glover	1966	This reference presents the findings of the author(s) concerning the measured cross section of known insects released from an aircraft and tracked by radar.	3.2 cm	Tobacco Hornworm*(Manduca sexta)	$1.8 cm^2$ (avg.)	JAFNA radar Wallops Island, Virginia	Various
				3.2 cm	Honey Bee Worker (Apis mellifera)	$1.8 \times 10^{-1} cm^2$		
				3.2 cm	Dragonfly	$1.2 \times 10^{-1} cm^2$		
			(Measurements continue on next page.)	10.7 cm	Tobacco Hornworm (Manduca sexta)	$1 cm^2$ (avg.)		

*Measured with wings removed.

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
G-7 (cont.)	Glover (cont.)	1966 (cont.)	(Aircraft Drop Measurements, continued)	10.7 cm	Tobacco Hornworm (Manduca sexta)	1.2×10^{-1} cm^2 (avg.)		
				10.7 cm	Honey Bee (Apis mellifera)	2×10^{-2} cm^2		
				10.7 cm	Dragonfly	4×10^{-4} cm^2		
				71.5 cm	-	Below detection threshold		
G-8	Glover	1966	The author(s) present the findings in reference G-7 with larger figures and a slant toward the layman.	Same as in preceding reference	Same as in preceding reference	Same as in preceding reference	Same as in preceding reference	Same as in preceding reference
G-10	Gorelik	1966	The author(s) studied the vertical velocities of clear air radar echoes. Insects were thought to be one primary source of these returns. The radar parameters are not given and specific insects are not identified.	UNKNOWN	UNKNOWN	10^{-1} cm^2	Pulse coherent radar	Characteristics unknown
G-13	Gorelik	1968	The author(s) present their findings of investigations on clear air radar echoes in Russia. Balloon traps were set and insects were caught; however, no radar cross section data pertaining to the trapped insects is presented. This reference is presented with others containing data on insect	-	-	-	-	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect		Measurement System Type and Location	Range Resolution
G-13 (cont.)			measurements because it is possible that the original Russian document may have had a stronger linkage between the observed clear air echoes and the trapped insects.						
H-2	Hajovsky	1966	This work has been used as a primary reference by most of the other authors cited. The measurements were made on known insects and were taken under reasonably well controlled conditions. Effects of polarization were considered. The values σ_L and σ_T refer to the E field orientation to the insect's body in longitudinal and transverse dimensions, respectively.	3 cm	Type of Insect	σ_L cm^2	$\sigma_T$cm^2	Laboratory Set up	Not applicable
					Range Crane Fly (Diptera: Timpula simplex)	3×10^{-1}	2×10^{-2}		
					Green Bottle Fly (Diptera: Lucilia caesar)	2.5×10^{-1}	1×10^{-1}		
					Honey Bee (Hymenoptera: Apis mellifera)	1.00	3×10^{-1}		
					California Harvester Ant (Hymenoptera: Pogonomyrmex californicus)	4×10^{-2}	2×10^{-2}		
					Convergent Lady Beetle (Coleoptera	2×10^{-2}	1×10^{-2}		

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect		Measurement System Type and Location	Range Resolution
H-2 (cont.)	Hajovsky (cont.)				Hippodamia convergens)	σ_L cm^2	σ_T cm^2		
					Twelve Spotted Cucumber Beetle (Cleoptera: Diabrotica duodecimpunctata)	1.4×10^{-1}	5×10^{-2}		
					Army Worm Moth (Lepidoptera: Cirphis unipuncta)	1.22	1.2×10^{-1}		
					Alfalfa Caterpillar Butterfly (Lepidoptera: Colias eurytheme)	6.5×10^{-1}	2×10^{-2}		
					Blue Winged Locust (Orthoptera: Trimeratropic dyanipennis)	9.60	9.6×10^{-1}		
					Spider (Aranedia)	1×10^{-1}	6×10^{-2}		

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
H-5	Hardy	1969	The author(s) review the research that has been done on the subject of clear atmospheric probing by high power, high resolution radar. The author(s) measure the characteristics of clear air returns using three (3) wavelengths simultaneously. The predominance of Rayleigh scatterers leads the author(s) to conclude that insects are one major source of the observed clear air returns. Typical insect cross sectional values are shown (taken from other references) but original measurements on known insects are not presented.	-	-	-	-	-
H-8	Hardy	1966	The research reported in this reference was undertaken to investigate the origin of clear air echoes. The detection of insects is inferred on the basis of the author(s) measurements of unknown targets being compared to typical radar cross sections known to exist for insect targets. Since the targets observed were not identified the broad range of cross sections recorded will not be presented.	-	-	-	-	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
K-1	Katz	1966	The author reviews a small portion of insect measurement work as part of a broader review of radar research on clear air returns. The insect measurements shown in K-5 are treated in a cursory manner. Thus measurement data will be presented in the following reference.	-	-	-	-	-
K-5	Konrad	1968	The author discusses the use of the JAFNA radar at Wallops Island as a tool to probe the clear atmosphere. Meteorological, ornithological, and Entomological implications and results pertaining to past studies are discussed.	10 cm	Tobacco Hornworm (Manduca sexta)	Approximately $1x10^{1}$ to $2x10^{-1}$ cm^2 average value approximately $1cm^2$	-	-
					Tobacco Hornworm*	Fairly smooth values around $2x10^{-1}cm^2$		
L-6	Lofgren	1969	The author(s) made Doppler velocity and polarization measurements on 860 angel echoes with a vertical pointing Doppler radar. Target sources were not identified. The presence of insects was implied as one source of "angel" echoes.	3.25 cm	UNKNOWN	$8x10^{-5}$ to $1.3x10^{-1}cm^2$	Vertical Pointing Dual Polarized Doppler radar	152 meters

*Wings removed.

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
P-10	Pollon	1970	CLASSIFIED. All data pertaining to insect measurement presented elsewhere.					
R-10	Reedy	1975	The author(s) interest in radar measurement of insects cross sections was incidental to Entomological studies. However, in pursuing their reasons for study they reviewed many of the insect measurements that were conducted before 1975. Several tables showing insect cross section as a function of insect type and frequency were generated. Much of the data presented on insects was taken from references G-7 and H-2 and thus will not be presented again.	-	-	-	-	-
R-15	Richter	1972	The author(s) describes tethered balloon measurements of the Cabbage Looper Moth and Field Cricket. The author(s) conclude that by conducting statistical analysis on a large number of insects it should be possible to distinguish between swarms of different insects. (Conclusion is based on cross section differences).	10.35 cm 10.35 cm	Cabbage Looper Moth (Trichoplusia ni) Field Cricket (Acheta assimilis)	$2.10^{-3}cm^2$ $1cm^2$	Near Vertical pointing FM/CW radar owned by NELC	Assumed 1 meter

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
R-17	Richter	1973	The author(s) expand on the preceding referenced work and present additional data concerning observations of the clear atmosphere during the measurement period.	See preceding reference	See preceding reference	See preceding reference	See preceding reference	See preceding reference
R-18	Riley	1973	The author conducted laboratory cross section measurements on three insects and presents very abbreviated findings. Cross section is averaged over an aspect angle of 180°.	3.18 cm	Desert Locust (Schistocerca gregaria)	Averaged over 180° 1.4 to .8cm^2	-	-
					African Locust (Locusta Migratoria migratorioi-des)	$5x10^{-1}$ to $9x10^{-1}cm^2$		
					Cotton Leaf-worm (Spodoptera litoralis)	$8x10^{-1}cm^2$		
R-19	Riley	1974	The author discusses the radar observations of desert locusts under free flight conditions. Data agrees with the previous reference. Laboratory measurements of locust cross sections are presented.	3.2 cm	Locust male & female (Schistocerca gregaria)	Peak $5cm^2$ average $1cm^2$	Laboratory Set up	UNKNOWN

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
R-20	Riley	1975	The author presents his findings on flying locust orientation versus the direction of the wind. The difference in radar cross section between broadside and tail aspect angles is used to imply body orientation. Horizontal polarization was used to enhance the differences in observed cross sections. No absolute cross section data is given.	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
R-24	Roffey	1972	The author reviews much of the work done by others prior to his publication date. Radar/insect study programs are recommended on the basis of the supporting literature. Reference contains good survey of the prior work.	-	-	-	-	-
S-3	Schaefer	1970	The author reports on field measurements of desert locust.	3 cm	Desert Locust (Schistocerca gregaria)	$5cm^2$ side aspect $3x10^{-1}cm^2$ end aspect	-	-
S-4	Schaefer	1976	Section 8 of the RES symposium on Insect Flight edited by R. C. Rainey. Numerous data on insect/radar measurements are presented.	-	-	-	-	-

(Table I, continued)

Reference ID No.	First Author	Year of Publication	Description of Work and the Resulting Data	Wavelength at Which Measurement was made	Insect(s) Measured by the Author	Cross Section of Measured Insect	Measurement System Type and Location	Range Resolution
T-1	Tarbell	1972	The author measured mosquito cross sections using a Doppler radar and moving air column. Measurements were also made by inserting the insect in a "slotted" line. No meaningful results were obtained using the Doppler technique. This work is referenced in D-5.	3.15 cm	Humidified dead mosquito	$1x10^{-5}cm^2$	Laboratory Measurement System	-
					alive	$5x10^{-4}cm^2$		
				1.88 cm	Humidified dead-mosquito	$2x10^{-4}cm^2$		
					alive	$1x10^{-2}cm^2$		
T-3	Tolbert	1958	The author(s) report on clear air echoes received with a dual wavelength vertically pointing millimeter radar. The conditions under which the insect measurements were made are unknown.	8.6 mm and 4.3 mm (measurements at 8.6 mm shown)	House fly (type unknown)	$1x10^{-1}cm^2$	Vertical Pointing Pulsed System	3 meters
					Moth (type unknown) dead 1 day	$1.5x10^{-1}cm^2$		
					House fly (type unknown) dead 2 days	$1x10^{-2}cm^2$		
T-4	Tolbert	1958	The same basic data as presented above.	-	-	-	-	-

The "quick reference" was developed to allow the user to determine which papers may be of interest for his further study. In general it was found that most references were readily available.

E. Availability of References

A large number of the references shown in the Master index were found to be available through the Georgia Institute of Technology library. Two complete sets of all located references were generated. One set is held by the authors of this report and the other set was sent to the project monitor, Mr. W. W. Wolf at the Western Cotton Research Laboratory, Phoenix, Arizona.

Section II

SEARCH TECHNIQUE

The search for published work concerning the radar reflectivity of insects involved a multi-step process. First, publications on file at Georgia Tech were reviewed. References to additional work were obtained from these "on-hand" publications. The next step was to further expand the search by reviewing the references in 3 computerized data bases. The hard copy and microfilm copies of the references thought to be relevant to insect radar cross section studies were obtained.

Figure 3 is a flowchart showing a detailed breakdown of the steps taken in this literature search. An index, referred to as the Georgia Tech Master Bibliography, was developed and maintained during the literature search. This Master bibliography index, along with a key for its use, constitutes Appendix I.

A. The Search and Capture Procedure

First, documents known to contain insect cross section measurements were first consulted. One such source was a Georgia Tech document entitled The HOWLS Radar Sky-Clutter Environment by Reedy and Cutler, published in 1975. This document contains other references on the radar reflectivity of insects. Other publications such as Insect Flight, edited by Rainey, were available at the start of this literature search. These documents, journals and reference books were reviewed for insect measurement data and to find other pertinent references. All references that were on hand at Georgia Tech when the project began are thus referred to as "on-hand references".

A total of 65 titles (thought to contain insects and radar measurements) were identified using the "on-hand" sources. An additional seventy

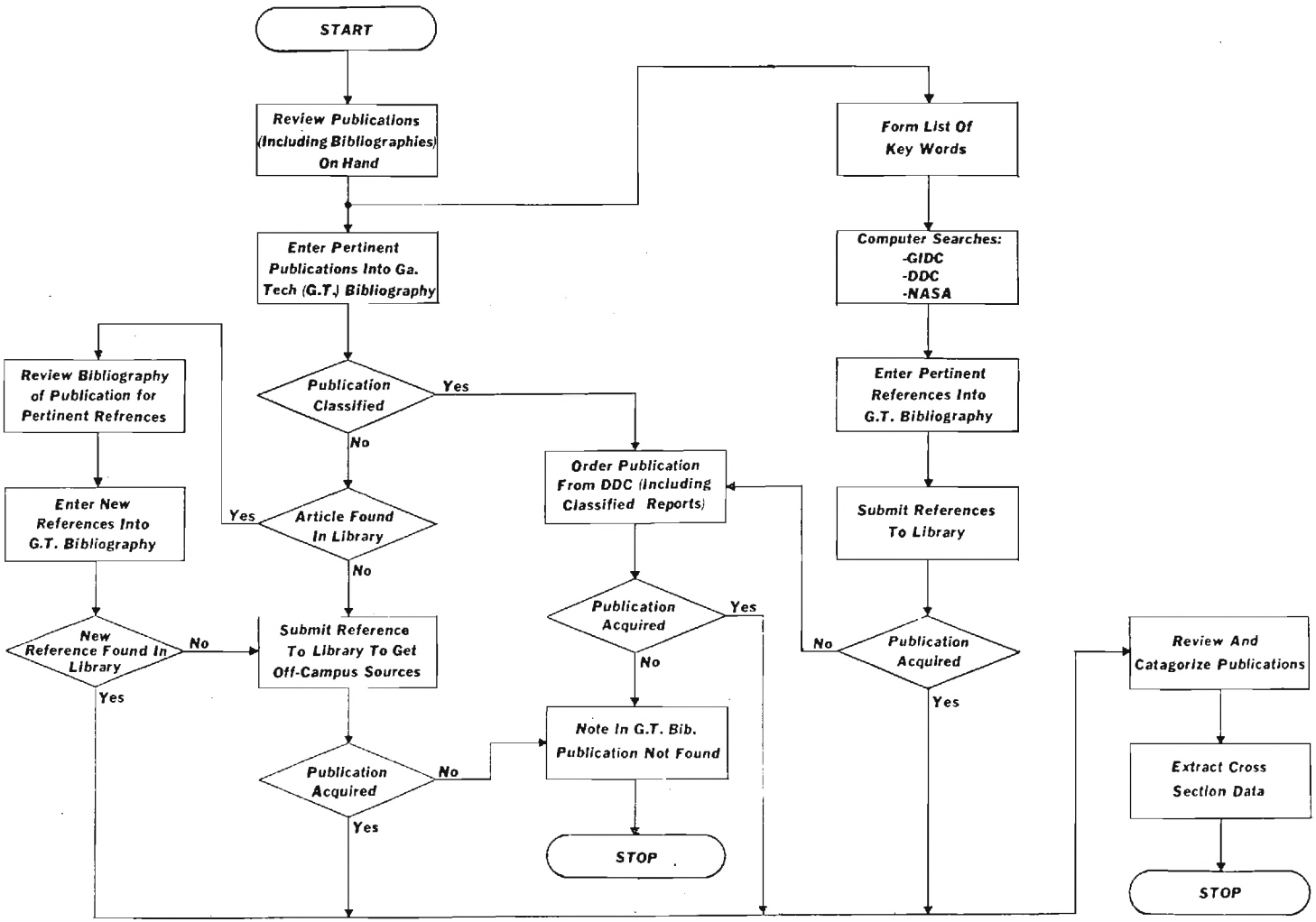

Figure 3. Flow-chart showing steps taken in conducting the Literature Search

titles relevant to, but not dealing primarily with insect/radar measurements, were identified. The goal during step two was to search for the actual hard copy of each reference at the Georgia Tech Price Gilbert Memorial Library, which contains 850,000 volumes; 1,000,000 microtexts, 220,000 other bibliographical units and 12,000 serials and 6,500 periodicals with about 75% of these being in scientific and technical fields.

Hard copies and microfilm of the references not found at the Georgia Tech library were submitted to the Information Exchange Center (IEC) for location by professional librarians. The IEC used off-campus sources (such as other libraries) if the source could not be found at the Georgia Tech library. After a reasonable time when publications were not found or could not be obtained, the search ceased. The references that could not be located are noted in the Georgia Tech Master Bibliography Index.

Seventy hard copy or microfiche works were located during the search phase at the Georgia Tech library. The references used by the author of each of the located works were then checked to determine what new references might exist. When new references were found they were entered into the project Master Bibliography, and were subsequently sought at the library. If hard copies of the new references could not be found at the Georgia Tech library, the IEC was requested to use professional library staff to search for the work.

B. Computer Search

Another group of titles thought to be pertinent was obtained through computer searches. The three computer data bases searched were: (1) the Georgia Information Dissemination Center (GIDC), which includes the National Technical Information Service (NTIS); (2) the Defense Documentation Center

(DDC); and (3) the National Aeronautical and Space Administration's (NASA) NASA Scan files. These three data bases receive articles and reports from various sources. When a reference is prepared for entry into these data bases, an abstract is prepared and keywords that describe the subject matter are selected. Bibliographical information (title, author, data of publication, etc.) is also stored as part of the computer record.

This data is retrieved by computer on the basis of a "keyword" matching technique. The range of keywords may be broad in scope and can include the names of authors known to have conducted insect/radar measurements.

C. Data Bases Searched

The first computer literature search used was the Georgia Information Dissemination Center (GIDC) search. The GIDC is based at the University of Georgia in Athens, but is available through the Georgia Tech library. The GIDC includes many data bases from a variety of fields. Two of the most relevant data bases (subject areas) were scanned during the GIDC search.

The first data base searched within the GIDC was the National Technical Information Service (NTIS) (or U. S. Government Reports) which is prepared by the U.S. Department of Commerce. The NTIS files contain over 600,000 citations from 1964 to the present. This data includes the reports of over 300 federal government agencies. Specifically, government sponsored research, development, and engineering reports, plus analyses, journal articles, and translations prepared by federal agencies, their contractors or grantees are contained in the NTIS data base. The scope of NTIS includes aeronautics, agriculture, astronomy and astrophysics, behavioral/social sciences, biological and medical sciences, chemistry, earth sciences, oceanography, electronics, engineering, energy, materials, mathematical sciences, military

sciences, communications, and space technology. The titles in the NTIS data base correspond to Weekly Governmental Abstracts and semi-monthly Government Report Announcements.

The second data base searched was the BIOSIS Previews. The BIOSIS Previews contains citations from both Biological Abstracts (BA) and Bioresearch Index. Together, these publications constitute the major English language service providing comprehensive worldwide coverage of research in the life sciences. Biological Abstracts includes approximately 140,000 titles collected on a yearly basis from nearly 8,000 primary journal and monograph titles. Bioresearch Index includes an additional 100,000 citations a year, from symposia, reviews, preliminary reports, semi-popular journals, selected institutional and government reports, research communications, and other secondary sources. BIOSIS Previews includes over 1,400,000 citations from 1968 to the present. All life sciences are covered, including entomology, which pertain to the subject of the Georgia Tech literature search.

The first step taken to survey the literature existing in the computerized data base was the development of a "keywords" list. The "on-hand" articles and bibliographies were reviewed. A list of keywords appearing in the literature on radar measurements of insects was made and appears in Table II. This list of keywords was very broad and was meant to include all terms remotely related to radar reflectivity measurements of insects. Some examples of these keywords (see Table II) include radar, high resolution, cross section, insect, entomology, angel, clear air, and false targets.

Various authors who were known to have made radar/insect measurements were also included as keywords. Weighting functions were assigned to each keyword. The GIDC search produced a total of 4,904 citations to be reviewed.

Table II

Keywords Used In The Computerized Search of the GIDC Data Base

GIDC KEYWORDS	GIDC KEYWORDS and AUTHORS
Angel	Mysterious Target
Anomal (sic)	Radar
Atmosphere	Resolution
Backscat (sic)	Track
Bug	Troposphere
Bugs	Unexplained Target
Centimeter Measur (sic)	Unknown Target
Clear Air	Deam A.P.
Clear Atmosphere	Glover K.M.
Cross Section	Hardy K.R.
Echo	Lagrone A.H.
Entomolog (sic)	Lhermitte R.M.
False Target	Rainey R.C.
High Speed Target	Richter J.H.
Insect	Riley J.R.
Locust	Roffey J.
Microwave	Schaefer G.W.
Moth	

D. GIDC Search Results

The 4,904 GIDC abstracts "pulled" by the keywords in Table II produced only 26 citations that were thought to be relevant to the central research theme. Upon closer examination it was determined that 4 of these citations were already on hand in the Master Bibliography file. The 22 remaining references were added to the Master index processed for the location of hard copies.

An analysis was conducted to determine why only .5% of the 4,904 located citations pertained to insect measurements. It was determined that the keywords were too broad. For example, many of the citations concerning atmospheric effects on radar reflectivity were not related to insects. The lesson learned with the GIDC search was that references pertaining specifically to the radar reflectivity of insects could be obtained with a much narrower field of keywords; therefore, the keyword list was reduced in order to decrease the number of irrelevant citations. Thus, for the DDC and NASA computer searches, the only keywords used were "radar" and "insect". This reduced the number of retrieved reference titles and all but one were found to be relevant.

E. DDC Search (Classified Abstracts)

A second computer literature search was made of the Defense Documentation Center data base. The DDC is the clearinghouse for the Department of Defense's collections of research and development documentation in virtually all fields of science and technology involving subject categories ranging from aeronautics to zoology. In-house service labs and private contractors are required to deposit information (both classified and unclassified, including CONFIDENTIAL, SECRET, and RESTRICTED data) into the DDC data base for the withdrawal by eligible users.

F. DDC Search Results

The DDC search, run with the keywords "radar" and "insects" produced 22 citations. Of these 22 citations, 15 were already part of the project Master Bibliography; seven citations were new and thus were added to the Georgia Tech Master Bibliography. Only three publications cited (C-10, S-9, S-10) were classified, and one of these (C-10) was already on file at Georgia Tech. All of the publications cited had some mention of insects in association with radar.

G. NASA Search

The third and last computer search made was the NASA computerized literature search. The NASA literature search is based on a computerized records search of the technical reports, journal articles, books, conference papers, and other publications stored in the NASA scientific and technical information system. Most of the documents contained in the NASA data base had been announced either in NASA's abstract journal, Scientific and Technical Aerospace Reports (STAR) or in International Aerospace Abstracts (IAA), an abstract journal published by the American Institute of Aeronautics and Astronautics (AIAA) under a NASA contract.

H. NASA Search Results

Using the keywords "insect" and "radar" the NASA search produced 23 references. Seven of these were references that were "new" and thus were added to the Master Georgia Tech Bibliography. None were classified. The citations included about the same amount of data (authors, title, date, source, and keywords) as the GIDC computer literature search. An example of a NASA citation is shown in Figure 4.

The new pertinent references from these three computer searches (GIDC, DDC, and NASA) were entered into the Georgia Tech Master Bibliography

68A13146*# ISSUE 6 PAGE 984 CATEGORY 7 67/00/00 5 PAGES
UNCLASSIFIED DOCUMENT
  DOT ANGELS - INSECTS AND BIRDS.
  RADAR TRACKING OF DOT ANGELS, BIRDS AND INSECTS, STUDYING POSSIBLE NONMETEOROLOGICAL ORIGIN OF ANGELS
  A/GLOVER, K. M.; B/HARDY, K. R. (AB/USAF, OFFICE OF AEROSPACE RESEARCH, CAMBRIDGE RESEARCH LABS., BEDFORD, MASS./.)
  BOSTON, AMERICAN METEOROLOGICAL SOCIETY, P. 264-268.
USAF-NASA-SUPPORTED RESEARCH. IN- AMERICAN METEOROLOGICAL SOCIETY, CONFERENCE ON RADAR METEOROLOGY, 12TH, U. OF OKLAHOMA, NORMAN, OKLA., OCT. 17-20, 1966. PROCEEDINGS. <A68-18122 06-20<
  /*BIRDS/*INSECTS/*RADAR ECHOES/*RADAR TRACKING/ CONFERENCES/ RADAR CROSS SECTIONS/ RADAR SIGNATURES/ TRACKING RADAR

68A13144*# ISSUE 6 PAGE 983 CATEGORY 7 67/00/00 5 PAGES
UNCLASSIFIED DOCUMENT
  RADAR CHARACTERISTICS OF KNOWN INSECTS IN FREE FLIGHT.
  AUTOMATIC RADAR TRACKS OF VARIOUS INSECT SPECIES IN FREE FLIGHT SUGGEST DOT ANGEL ECHOES ARE DUE TO INSECTS
  A/GLOVER, K. M.; B/HARDY, K. R.; C/KONRAD, T.; D/LANDRY, C. R. (AD/USAF, OFFICE OF AEROSPACE RESEARCH, CAMBRIDGE RESEARCH LABS., BEDFORD, MASS./, AC/JOHNS HOPKINS U., APPLIED PHYSICS LAB., BALTIMORE, MD./.)
  BOSTON, AMERICAN METEOROLOGICAL SOCIETY, P. 254-258.
USAF-NASA-SUPPORTED RESEARCH. IN- AMERICAN METEOROLOGICAL SOCIETY, CONFERENCE ON RADAR METEOROLOGY, 12TH, U. OF OKLAHOMA, NORMAN, OKLA., OCT. 17-20, 1966. PROCEEDINGS. <A68-18122 06-20<
  /*INSECTS/*RADAR ECHOES/*RADAR TRACKING/ AUTOMATIC CONTROL/ CONFERENCES/ ENTOMOLOGY/ FREE FLIGHT/ RADAR CROSS SECTIONS

Figure 4. An example of a NASA Search Citation.

The new references to the unclassified publications were submitted to the Georgia Tech library Literature Location Service to be acquired.

I. Summary of Computer Search Results

The results of the computer searches (number total citations, number pertinent citations, etc.) are listed in Table III. The 26 pertinent references found in the GIDC search, 21 of 22 references located in the DDC search, and 21 of 22 pertinent references in the NASA search were obtained. Several of these publications are on file as microfiche. Unclassified reports that were not found, classified reports that were not "on hand" at Georgia Tech, and other classified reports referenced earlier in the literature search were ordered from the Government Document Center at the Georgia Tech library. When the publication could not be obtained, this fact was noted in the Master Bibliography (Appendix I).

J. The Master Bibliography Index

The Master Bibliography Index produced by this literature search appears in Appendix I. The Master Bibliography Index is alphabetized according to the author's last name, or lacking a name, the first word in the title of the publication. Each reference is organized in an alphabetical reference scheme. The articles are numbered using their alphabetical identifier and a sequence number (A-1 through A-16, B-1 through B-18, etc.).

K. Selection of Relevant References

After all hard copy and microfiche were acquired, the publications were separated into two categories. The pertinent publications were sorted from those which had little or no useful information on insect measurements. Each publication was read and assigned a category according to its relevance to radar cross section measurements of insects. These various categories are listed at the beginning of Appendix I.

Table III

Citations Found In Each Category From Each Computer Data Base

COMPUTER SEARCH	TOTAL CITATIONS	PERTINENT CITATIONS (cat. 1-5)	NEW REFERENCES (to G.T. Bib.)	PERTINENT REFERENCES FOUND	CLASSIFIED REFERENCES	CLASSIFIED REFERENCES FOUND
GIDC	4904	26	22	26	0	0
DDC	22	22	7	21	3	3
NASA	23	22	7	21	0	0

Category 1 publications were either found in Georgia Tech's files as "on hand" references when the project started or in a bibliography of one of these publications. Each had to meet one of the five criteria listed in Section I to qualify as a category 1 reference. Publications in category 2 also contain specific radar cross section measurement data but were found later in the literature search. An example of a category 2 reference would be an article cited in a computer search. References found by both the "early" method and computer search would be listed in both categories (1 and 2). Thus, the publications in categories 1 and 2 are those of primary importance to the fulfillment of the goals of this literature search. Category 3 publications were "on hand" when the project started. Radar measurements of insects were mentioned in the category 3 references but the references did not contain actual cross section data. Publications in category 4 also discuss radar measurements of insects but give no actual cross section data. Publications in category 5 pertained to atmospheric effects on radar signals but contained no information relating directly to insects. These publications can serve as amplifying data on atmospheric effects that may be detected when looking for insects with radar. Several references mention insects only briefly, but give little or no quantitative information relating directly to insects. These publications were categorized as "5**". Publications in this category were either "on hand" as in categories 1 and 3 or were found later in the search. Category 6 publications were those found to be irrelevant. Publications in category 7 were thought to be pertinent, but were not found or were not obtained in the time available. An example of this type reference would be a report with limited distribution. Category 8 was assigned to publications which were read, but found to be irrelevant and not acquired. These were articles read at the Georgia Tech library.

A listing of the publications under each category appears in Table IV.

L. Classified References

The Master Bibliography Index contains the classification of the publication in the first column to the right of the entry. The four classifications of the entries used are "U" (UNCLASSIFIED), "C" (CONFIDENTIAL), "S" (SECRET), and "L" (Limited Distribution). When limited distribution is shown, the publication is restricted to users with a "need to read" even though the report itself may be unclassified. There are three entries (H-11, J-2, and N-1) which have limited distribution, but only one of these (N-1) is classified. None of these limited distribution publications could be obtained. There were a total of eight classified publications (C-9, C-10, F-2, H-11, J-2, N-1, P-10, S-9, S-10, S-16) in the bibliography. On these eight, four were "on hand" at Georgia Tech at the beginning of the project and the other four were sought; two were eventually acquired. The two classified references not found were N-1 and S-16.

Table IV

PUBLICATIONS SHOWN BY ALPHABETICAL INDEX NUMBERS

AND CATEGORY

*(Index numbers in parentheses denote the second listing of that index number.)

1	2	3	4	5	6	7	8
A-11	(A-11)*	A-10	A-3	A-1	L-3	A-12	A-2	A-15
A-14	(A-14)	B-10	A-5	A-4	L-4	A-13	C-8	B-13
A-16	(A-16)	C-5	B-5	A-6	L-5	C-1	G-12	B-16
B-3	B-1	C-7	(B-10)	A-7	L-7	E-1	H-11	C-6
B-15	(B-15)	C-9	C-3	A-8	M-1	F-9	H-12	D-3
C-4	B-17	C-10	(C-5)	A-9	M-3	H-14	H-16	F-10
D-5	(C-4)	C-12	(C-7)	B-2	M-6	K-2	J-2	G-6
F-4	F-2	D-1	(C-9)	B-4	M-7	R-26	L-1	G-14
F-8	(F-8)	F-11	(C-10)	B-6	N-2	(8 Total)	M-4	G-15
G-5	(G-5)	F-12	(C-12)	B-7	N-4		M-5	G-16
G-7	(G-7)	F-13	(D-1)	B-8	O-2		N-1	K-3
G-8	(G-8)	F-14	D-2	B-9	P-1		O-3	K-6
G-13	G-10	G-2	F-3	B-11	P-9		O-4	O-1
H-2	(H-2)	G-3	F-6	B-12	R-1		R-4	R-13
H-5	(H-8)	H-4	(G-2)	B-14	R-2		R-12	S-17
H-8	K-1	H-6	(G-3)	B-18	R-11		R-21	(15 Total)
L-6	K-5	H-7	(H-6)	C-2	R-14		R-25	
P-10	(R-10)	H-13	H-15	C-11	R-16		S-6	
R-10	(R-17)	K-8	J-1	D-4	R-22		S-13	
R-15	(R-19)	L-2	(L-2)	E-2	S-1		S-16	
R-17	R-20	M-2	(M-2)	F-1	S-9		T-5	
R-18	(S-4)	M-8	P-2	F-5	S-10		(21 Total)	
R-19	(T-1)	N-3	P-3	F-7	S-14			
R-24	(T-3)	P-4	(P-4)	G-1	T-2			
S-3	(T-4)	P-7	P-5	G-4	U-1			
S-4	(25 Total,	P-8	P-6	G-9	V-1			
T-1	7 1st time)	R-3	(P-7)	G-11	V-2			
T-3		R-5	(R-5)	G-17	Y-1			
T-4		R-6	(R-6)	G-18	(63 Total)			
(29 total)		R-7	R-8	H-1				
		R-9	S-2	H-3				
		R-23	S-11	H-9				
		S-5	S-15	H-10				
		S-7	(33 Total,	K-4				
		S-8	17 1st time)	K-7				
		S-12						
		(36 Total)						

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2. G. W. Schaefer, "Taking Advantage of Moths and Locusts," Scientist, November 28, 1974, p. 653.

3. R. C. Rainey, "Observations of Desert Locust Swarms by Radar," Nature, 1955, p. 77.

4. J. R. Riley, "Angular and Temporal Variations in the Radar Cross-Sections of Insects," Proc. IEEE, Vol. 120, No. 10, October 1973, p. 1229-1232.

5. J. R. Riley, "Radar Observations of Individual Desert Locusts," Bull. Ent. Res., 1974, p. 19-32.

6. "G. W. Schaefer, "Radar Detection of Individual Locusts and Swarms," Proc. Int. Conf. Acridology, London (1970), 1972, p. 379-380.

7. G. W. Schaefer, "Radar Observations of Insect Flight," Insect Flight, 1976, p. 157-196.

8. R. G. Hajovsky, A. P. Deam, and A. H. LaGrone, "Radar Reflections from Insects in the Lower Atmosphere," IEEE Trans. on Antennas and Propagation, Vol. 14, 1966, p. 224-227.

9. J. R. Riley, "Collective Orientation in Night-Flying Insects," Nature, Vol. 253, January 10, 1975, p. 113-114.

10. K. M. Glover and K. R. Hardy, "Dot Angels: Insects and Birds," Proc. Twelfth Weather Radar Conf., 1966, p. 264-268.

11. K. R. Hardy and I. Katz, "Probing the Atmosphere with High Power, High Resolution Radars," Proc. IEEE, Vol. 57, April 1969, p. 468-480.

12. T. G. Konrad, "Radar as a Tool in Meteorology, Entomology, and Ornithology," Fifth Symp. on Remote Sensing of Environment, April 1968, p. 655-665.

13. K. M. Glover, K. R. Hardy, and C. R. Landry, "Radar Characteristics of Known Insects in Free Flight," Proc. of the Twelfth Conference on Radar Meteorology, 1966, p. 254-258.

14. J. D. Downing and E. L. Frost, "Recent Radar Observations of Diurnal Insect Behavior," Proc. of the 59th Ann. Meeting of the N.J. Mosquito Extermination Assoc., 1972, p. 114-131.

15. W. Fishbein, E. Frost, and M. W. Vander Meer, "Doppler Discrimination as Solution to the Radar Angel Problem," Sixteenth Annual Tri-Service Radar Symposium, June, 1970.

16. E. L. Frost, "Radar Returns and Correlated Insect Trapping Data," Proc. of the 58th Ann. Meeting of the N.J. Mosquito Extermination Assoc., March 1971, p. 81-92.

17. E. L. Frost, "Tracking Insect Swarms by Radar: A Feasibility Study," Proc. of the 57th Ann. Meeting of the N.J. Mosquito Extermination Assoc., March 1970, p. 38-42.

18. E. L. Frost and J. Robinson, "Radar Entomology on the Great Plains," Proc. of the 60th Ann. Meeting of the N.J. Mosquito Extermination Assoc., March 1973, p. 160-169.

19. E. K. Reedy and T. D. Cutler, "The HOWLS Radar Sky -- Clutter Environment," Georgia Institute of Technology, Engineering Experiment Station, Atlanta, September 15, 1975.

20. A. Tarbell, "Small Radar Cross Section Measurements," USAECOM-4008, August, 1972.

APPENDIX I

The Georgia Tech Master Bibliography

Index on References Pertaining to Radar

Measurements on Insects.

APPENDIX I

Key to the Master Bibliography Index

The Master Bibliography Index is alphabetized according to the first author's last name; or if the author's name is unavailable, the first work in the title of the publication is used. The publications are catalogued in three classification systems.

I. "Class" -- Classification

The classification of the publication, if known, is given as "U" (Unclassified), "C" (Confidential), "S" (Secret), or "L" (Limited Distribution). Limited Distribution does not mean that the publication is necessarily classified. The sponsor of the research leading to publication of the technical report of interest may have restricted the distribution to those with a "need to read". These type reports may sometimes be obtained from the sponsoring agency. No "C", "S", or "L" hard copies appear in the compendium of the hard copy references sent to the sponsor.

II. "On Hand"

References catalogued "Y" (Yes) denote Georgia Tech has the publication. A copy of a "Y" publication was also sent to the sponsor. References catalogued "N" (No) denote Georgia Tech does not have the publication.

References catalogued "Y*" denote Georgia Tech has the publication, but for reasons of classification, length, or irrelevance, the publication was not sent to the sponsor.

III. "Cat." -- Category

Each publication was read and assigned to a general category. The category descriptor was assigned on the basis of its relevance to radar cross section measurements of insects and its availability. The categories (1-8) are as follows:

1. Publication was found in the Georgia Tech "on hand" files when the project started and contained specific radar cross section measurement data.

2. Publication was found later in the literature search and contained specific radar cross section measurement data.

3. Publication was found in the Georgia Tech "on hand" files when the project started and it discussed radar measurements.

4. Publication was found later in the literature search and discussed radar measurements of insects, but did not contain actual cross section data.

5. Publication was found at some point in search (either "on hand" or later in search) and pertained to atmospheric effects in general, serving as amplifying data for anyone interested in insects/radar research. References catalogued as "5**" denote that the publication briefly mentions insects.

6. Publication was acquired, but was found to be irrelevant.

7. Publication appeared to be pertinent, but was not found or was unable to be obtained.

8. Publication was read but was found to be irrelevant and was not acquired.

Publications catalogued "1 & 2" or "3 & 4" denote publication was found in Georgia Tech files "on hand" and also was found later in the literature search.

This indexing scheme is used in the Master Reference. Information relating to the publication or the acquisition status of the publication is found in parentheses in the Master Bibliography Index for certain entries. If the publication was found in more than one source, both sources are given.

BIBLIOGRAPHY

NOTE: For items marked *, part of file kept at Georgia Tech, but does not appear in the copied appendix.

For items marked **, for a Category 5 only: briefly mentions insects.

No. Ref.		Class.	On Hand	Cat.
A-1	ABLE, K. P. "A Radar Study of the Altitude of Nocturnal Passerine Migration." Georgia Univ., Athens, Dept. of Zoology. March 70. 10 p.	U	Y	5
A-2	ASPLINDEN, C. I. and RAINEY, R. C. "Meteorology and the Migration of Desert Locust." W.M.O. Technical Note 54. 1963. p. 54-103.	U	N	7
A-3	ASPLINDEN, C. I. and RAINEY, R. C. "Synoptic Meteorology and Locust Control." W.M.O. Bulletin, 10, 1. 1961. p.155-161.	U	Y	4
A-4	ATLAS, D. "Advances in Radar Meteorology." Advances in Geophysics. 10. N.Y. Academic Press. 1964. p. 317-479. (only p. 432-479 copied)	U	Y	5**
A-5	ATLAS, D. "Angels in Focus." Journal of Research of the Nat. Bur. of Standards. June 65. 69 D, No. 6, p. 871-875. (SA-65-30607, I-A65-27494). Also found in: World Conf. on Radar Met. (Incorp. 11th Weather Radar Conference). 1964. p. 25 (I-A65-11983). (copied from first source, J. of Res. of NBS)	U	Y	4
A-6	ATLAS, D. "Meteorological Angel Echoes," Journal of Meteorology. 1959. Vol. 16, p. 6-11.	U	Y	5
A-7	ATLAS, D. "Possible Key to the Dilemma of Meteorological 'Angel' Echoes." Journal of Meteorology. April 1960. Vol. 17, p. 95-103. (MG-60-11H-4).	U	Y	5

No. Ref.		Class.	On Hand	Cat.
A-8	ATLAS, D. "Radar Detection of the Sea Breeze." Journal of Meteorology. 1960. Vol. 17, p. 244-258.	U	Y	5**
A-9	ATLAS, D. "Radar Studies of Meteorological 'Angel' Echoes." Journal of Atmospheric and Terrestrial Physics. 1959. Vol. 15, p. 262-287.	U	Y	5**
A-10	ATLAS, D. "Use of Radar to Probe the Properties of the Cloudless Atmosphere." Meteorological Magazine. 1966. 95(1133), p. 379-381.	U	Y	3
A-11	ATLAS, D. and HARDY, K. R. "Radar Analysis of the Clear Atmosphere: Angels." Proc. XV General Assembly of URSI (Munich, 5-15 Sept. 1966). p. 401-469. Also found in: Progress in Radio Science, 1963-1966. (copied from Gen. Ass. of URSI)	U	Y	1 & 2
A-12	ATLAS, D.; HARDY, K. R.; and GLOVER, K. M.; et al. "Tropopause Detected By Radar." Science. 2 Sept. 1966. Vol. 153, p. 1110-1112. (I-A66-40304).	U	Y	6
A-13	ATLAS, D.; HARDY, K. R.; and KONRAD, T. G. "Radar Detection of the Tropopause and Clear Air Turbulence." Proc. Twelfth Weather Radar Conf., Boston: American Meteorological Society. 1966. p. 279-284.	U	Y	6
A-14	ATLAS, D.; HARRIS, F. I.; and RICHTER, J. H. "Measurement of Point Target Speeds with Incoherent Non-Tracking Radar: Insect Speeds in an Atmospheric Wave." Journal of Geophysical Research. 1970. Vol. 75 p. 7588-7596. Also found in: 14th International Meteorology Conf., 1971, Canada, p. 73-78. (both articles are included)	U	Y	1 & 2
A-15	ATLAS, D.; KERKER, M.; and HITSCHFELD, W. "Scattering and Attenuation by Non-spherical Atmospheric Particles." Journal of Atmospheric and Terrestrial Physics. 1953. Vol. 3, p. 108-119.	U	N	8

No. Ref.		Class.	On Hand	Cat.
A-16	ATLAS, D.; RICHTER, H.; and GOSSARD, E. E. "Waves, Turbulence, and Insects as Seen by Ultra High Resolution Radar." Univ. of Chicago. Oct. 1969. N00014-67-A-0285-0007. AD 705 622.	U	Y	1 & 2
B-1	BARRY, J. R.; CARTER, B. K; ERDAHL, R. J.; HARRIS, R. L.; and MILLER J. T. "Angel Clutter and the ASR Traffic Control Radar." Volume I. Study Results. Johns Hopkins Univ., Silver Spring, Md., Applied Physics Lab. Feb. 1973. 205 pages. AD 775 258. (only pages: 31, 57-58, 198-200 copied; GT/EES has complete report)	U	Y	2
B-2	.... Volume II. Appendices. 256 pages. AD 775 306.	U	Y*	5**
B-3	BATTAN, L. J. Radar Observation of the Atmosphere. Univ. of Chicago Press, Chicago. 1973. p. 245-274.	U	Y	1
B-4	BATTAN, L. J. "The Vertical Velocities of Angel Echoes." Proc. Tenth Weather Radar Conf., Boston: American Meteorology Society. 1963. p. 309-315.	U	Y	5**
B-5	BEAN, B. R.; MCGAVIN, R.E.; CHADWICK, R. B.; and WARNER, B. D. "Preliminary Results of Utilizing the High Resolution FM Radar as a Boundary-Layer Probe," Boundary-Layer Meteorology. 1971. Vol. I, p. 466-473.	U	Y	4
B-6	BERAN, D. W.; CHADWICK, R. B.; DECKER, M. T.; HALL, F. F.; and LITTLE, C. G. "Potential Capabilities of Four Lower Atmosphere Remote Sensing Techniques." Dec. 1971. 132 pages. COM-72-504(45) National Oceanic and Atmospheric Administration, Boulder, Colo. Wave Propagation Lab. (all insect data is in Bean, et al. "Prelim. Results ...")	U	Y*	5**

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B-9	BOLIE, V. W. "Theory of Scattering from a Nearly Transparent Anomaly." Applied Scientific Research, Sect. B (Netherlands). 1957. Vol. 6, No. 6, p. 422-428. (SB-58-1631; ET-58-574).	U	Y	5
B-10	BONHAM, L. L., and BLAKE, L. V. "Radar Echoes From Birds and Insects." Scientific Monthly. 1956. p. 204-209.	U	Y	3 & 4
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B-12	BORDEN, R. C., and VICKERS, T. K. "A Preliminary Study of Unidentified Targets Observed on Air Traffic Control Radars." Civil Aeronautics Administration. May 1953. 15 pages. AD 58 611.	U	Y	5
B-13	BROWN, F. A., Jr. "How Animals Respond to Magnetism." Discovery. 1963. p. 18-22.	U	N	8
B-14	BROWN, H. A. "Report on Radar Thin Lines." Proc. Eight Weather Radar Conf. Boston: American Meteorological Society. 1960. p. 65-72.	U	Y	5
B-15	BROWNING, K. A., and ATLAS, D. "Velocity Characteristics of Some Clear Air Dot Angels." Journal Atmospheric Science. 1966. Vol. 23. p. 592-604.	U	Y	1 & 2

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B-16	BROWNING, K. A., and WATKINS, C. D. "Observations of Clear Air Turbulence by High Power Radar." Nature. 1970. Vol. 227, p. 260-263.	U	N	8
B-17	BRYLEV, G. B. "Radar Probing of the Troposphere Under Clear Sky Conditions." Army Foreign Science and Technology Center, Wash. D. C., 19 Oct. 1970. 24 pages. AD 717 897.	U	Y	2
B-18	BRYLEV, G. B., and FEDORAV, A. A. "Space Time Characteristics of Clear Sky Radar Returns." Johns Hopkins Univ., Silver Spring, Md. Applied Physics Lab. 10 Nov. 1969. 24 pages. AD 700 421.	U	Y*	5
C-1	CAMHI, J. M. "Flight Orientation in Locusts." Scientific American. 1971. p. 74-81.	U	Y	6
C-2	CARLSON, A. V. "A Study of Anomalous Radar Reflections and Related Convective Instability." Proc. Twelfth Weather Radar Conference. 1966. p. 275-278.	U	Y	5**
C-3	CARLSON, A. V. "Radar Angels and Atmospheric Convection in Arizona." Army Electronics Command, Fort Huachuca, Arizona, Research Division. (401180). March 1967. 37 pages. AD 653 014. N67 329783-07.	U	Y	4
C-4	CHERNIKOV, A. A. "Radar Studies of Echoes From Clear Sky." (in Russian) Tsentral'naia Aerologicheskaia Observatoriia. Trudy, No. 48, 1963. p. 56-97 (English Translation: USAF Cambridge Research Laboratories, Bedford, Mass., Technical Report TR-480, July 1965). AD 621 419. N66 137483/13. 61 pages.	U	Y	1 & 2
C-5	CHERNIKOV, A. A. "Some New Soviet Investigations of Angel Echoes." Proc. Twelfth Weather Radar Conf. 1966. p. 291-292.	U	Y	3 & 4

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C-7	CHERNIKOV, A. A., and SHUPIATSKII, A. B. "Polarizatsionnye Kharakteristiki Radiolokatsionnykh Otrazhenii ot 'Iasnago' Neba (The Polarization Characteristics of Radar 'Angel' Echoes)." Izvest. Akad. Nauk SSSR., Fiz. Atmos.; Okeana Moscow. 1967. Vol. 3, p. 136-143. Also found in: Atmospheric and Oceanic Physics. 1967. Vol. 3, No. 2, p. 78-81. (copied from Atm. and Oc. Phys.)	U	Y	3 & 4
C-8	"Clear Air Clutter, A Survey of Data for the Artillery Locating Radar Application." TSC-PD-033-19. April 30, 1970.	U	N	7
C-9	CORRIHER, H. A., and PYRON, B. O. "A Bibliography of Radar Reflection Characteristics." Georgia Institute of Technology, Atlanta, Engineering Experiment Station.	U,C,S	Y*	3 & 4

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I	1952	U	Index to Vols. II and III
II	1952	C	Abstracts 1-967
III	1952	S	Abstracts 1001-1189
IV	1958	U	Index to Vols. V and IV
V	1958	C	Abstracts 2001-2770 and 3001J-3427J
VI	1958	S	Abstracts 4001-4378
VII	1967	U	Abstracts 5001-6321 and 7001J-8707J; Index to Vols. VII-X
VIII	1967	C	Abstracts 9001-9755
IX	1967	S	Abstracts 10001-10716
X	1967	SRD	Abstracts 11001-11375
XI	1969	U	Abstracts 12001-12665 and 13001J-13981J; Index to Vols. XI-XIV
XII	1969	C	Abstracts 15001-15184
XIII	1969	S	Abstracts 16001-16335
XIV	1969	SRD	Abstracts 16501-16599

(These volumes contain only abstracts. All pertinent articles and reports are listed separately in the bibliography. The categories of the pertinent articles and reports ranged from 1 to 5.)

No. Ref.		Class.	On Hand	Cat.
C-10	CORRIHER, H. A., and PYRON, B. O. "Abstracts on Radar Reflectivity of Air Targets." Georgia Institute of Technology, Atlanta, Engineering Experiment Station. Dec. 1968.	U,C,S	Y*	3 & 4

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II	C	250	AD 503 931
III	S	300	AD 504 019

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C-11	CRANE, R. K. "Measurement of Clear Air Turbulence in the Lower Stratosphere Using the Millstone Hill L-Band Radar." Mass. Inst. of Tech., Lexington Lincoln Lab. 17 Nov. 1970. p. 101-106. AD 723 792	U	Y	5
C-12	CRAWFORD, A. B. "Radar Reflections in the Lower Atmosphere." Proc. Inst. Radio Eng. 1949. Vol. 37, p. 404-405.	U	Y	3 & 4
D-1	DEAM, A. P., and LAGRONE, A. H. "Quantitative Observations of Dot Angel Echoes at Two Frequencies." Radio Science. 1965. Vol. I, p. 537-543. Also found in: Rep. P-2, NSF Grant GP-2596, 10 Jul. 65, Univ. of Tex., Elec. Eng. Res. Lab. (article copied from Radio Science)	U	Y	3 & 4
D-2	DEAM, A. P.; WALKER, G. B.; and LAGRONE, A.H. "Observations At and Near Vertical Incidence With an M-33 Radar." Scientific Report 6-56(AFCRL-63-921). 30 Nov. 1963. AF 19(604)-8038. AD 429 529. (report includes an estimate of insect cross section)	U	Y	4

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D-3	DONALDSON, R. J., Jr. "Resolution of a Radar Antenna for Distributed Targets." Journal of Applied Meteorology. 1965. Vol. 4, p. 727-740.	U	N	8
D-4	DOVIAK, R. J. "Comparison of Bistatic and Monostatic Radar Detection of Clear Air Atmospheric Targets." National Severe Storms Lab., Norman, Okla. 1972. 11 pages. COM-72-11008.	U	Y	5**
D-5	DOWNING, J. D., and FROST, E. L. "Recent Radar Observations of Diurnal Insect Behavior." Proc. of the 59th Ann. Meeting of the N.J. Mosquito Extermination Assoc. 1972, p. 114-131.	U	Y	1
E-1	EASTWOOD, Eric. "Radar: New Techniques and Applications." GEC-Marconi Research Lab., Chelmsford, England. May 1977. p. 101-109.	U	Y	6
E-2	EASTWOOD, Eric. "Radar Ornithology." The Chaucer Press, Ltd., Great Britain. 1967. p. 64, 185, 259.	U	Y*	5**
F-1	FEHLHABER, L., and GROSSKOPF, J. "Untersuchung der Struktur der Troposphere mit einem Vertikalradar (Investigation of the Structure of the Troposphere by means of Vertically Pointing Radar)." Nachrichtentechnische Zeitschrift. 1964. Vol. 17, p. 503-507. (article is in German; insects were only briefly mentioned)	U	Y	5**
F-2	FISHBEIN, W.; FROST, E.; and VANDER MEER, M. W. "Doppler Discrimination as Solution to the Radar Angel Problem." 16th Annual Tri-Service Radar Symposium. June 1970. (article was read and all insect cross section measurements given were from unclassified articles which are in the copied appendix)	C	Y*	2

No. Ref.		Class.	On Hand	Cat.
F-3	FISHBEIN, W.; FROST, E.; and VANDER MEER, M. W. "Investigation of Radar Anomalies." Army Elect. Com. Fort Monmouth, N.J. Combat Surveillance Target Acquisition Systems Integration Lab. 1970. 15 pages. AD 511 919 (was confidential, but was declassified)	U	Y	4
F-4	FISHBEIN, W.; FROST, E.; and VANDER MEER, M. W. "Some Measurements of Radar Angels (False Radar Targets). USAECOM Report.	U	Y	1
F-5	FLOCK, W. L. "Flight Safety Aspects of Precision Radar Near Air Bases in Bird Aircraft Collision Avoidance." Colo. Univ., Boulder. Oct. 1972. 66 pages. AD 751 985.	U	Y*	5**
F-6	FLOCK, W. L., and GREEN, J. L. "The Detection and Indentification of Birds in Flight Using Coherent and Noncoherent Radars." Proc. of the IEEE, Vol. 62, No. 6, June 1974. p. 745-753.	U	Y	4
F-7	FOWLER, M.S., and LAGRONE, A. H. "Bistatic and Monostatic Polarization Studies of Dot Angel Echoes." Report P-10, Texas Univ., Austin, Antennas and Propagation Div. (401 651) PB 174 698. 17 April 1967. 26 pages.	U	Y*	5**
F-8	FOWLER, M. S., and LAGRONE, A. H. "Comparison of Insect's Flight Characteristics with Observed Characteristics of Radar Dot Angels." Journal of Applied Meteorology. 1969. Vol. 8, p. 122-127.	U	Y	1 & 2
F-9	FRANKEL, M. S., and NORTH, E. M., Jr. "Two Radar Techniques for Remote Measurement of Atmospheric Parameters." Stanford Univ., Calif., Stanford Electronics Labs. Jan. 1972. AD 742 289.	U	Y*	6
F-10	FRIEND, A. W. "Theory and Practice of Tropospheric Sounding by Radar." Proc. IRE. 1949. Vol. 37, p. 116-138.	U	N	8
F-11	FROST, E. L. "Correlated Radar and Trapping Studies of Insect Swarming Over Atlantic Coastal Lowlands." Proc. of Seventh Intern. Symposium on Remote Sensing of Environment. 17-21 May 1971. p. 1905-1915.	U	Y	3

No. Ref.		Class.	On Hand	Cat.
F-12	FROST, E. L. "Radar Returns and Correlated Insect Trapping Data." Proc. of the 58th Ann. Meeting of the N.J. Mosquito Extermination Association. 17-19 March 1971. p. 81-92.	U	Y	3
F-13	FROST, E. L. "Tracking Insect Swarms by Radar: A Feasibility Study." Proc. of the 57th Ann. Meeting of the N.J. Mosquito Extermination Association. 11-13 March 1970. p. 38-42.	U	Y	3
F-14	FROST, E. L., and ROBINSON, J. "Radar Entomology on the Great Plains." Proc. of the 60th Ann. Meeting of the N.J. Mosquito Extermination Association. 14-16 March 1973. p. 160-169.	U	Y	3
G-1	GAUTHREAUX, S. A., Jr. "Radar Ornithology: Bird Echoes on Weather and Airport Surveillance Radars." Clemson Univ., S.C., Dept. of Zoology, Air Force Office of Scientific Research, Arlington, Va. 1 Feb. 1975. 54 pages. AD/A 006 425.	U	Y*	5**
G-2	GEHRING, W. "Analyse der Radarechos von Vogeln und Insekten." Der Ornithologische Beobachter. 1967. p. 145-151.	U	Y	3 & 4
G-3	GEOTIS, S. G. "On Sea Breeze 'Angels.'" Proc. Eleventh Weather Radar Conference. 1964. p. 6-9.	U	Y	3 & 4
G-4	GERRISH, H. P., and ANDREWS, G. F. "Fluctuations in Radar Video From a Diffuse Angel Pattern at Miami." Proc. Thirteenth Annual Weather Radar Conference. 1968. p. 230-235.	U	Y	5**
G-5	GLOVER, K. M. and HARDY, K. R. "Dot Angels: Insects and Birds." Proc. Twelfth Weather Radar Conference. 1966. p. 264-268.	U	Y	1 & 2

No. Ref.		Class.	On Hand	Cat.
G-6	GLOVER, K. M.; BOUCHER, R. J.; OTTERSTEN, H.; and HARDY, K. R. "Simultaneous Radar, Aircraft, and Meteorological Investigations of Clear Air Turbulence." Journal of Applied Meteorology. 1969. Vol. 8, p. 634-640.	U	N	8
G-7	GLOVER, K. M.; HARDY, K. R.; and LANDRY, C. R. "Radar Characteristics of Known Insects in Free Flight." Proc. of the Twelfth Conference on Radar Meteorology. 1966. p. 254-258.	U	Y	1 & 2
G-8	GLOVER, K. M.; HARDY, K. R.; KONRAD, T. G.; SULLIVAN, W. N.; and MICHAELS, A. S. "Radar Observations of Insects in Free Flight." Science. 1966. Vol. 154, p. 967-972.	U	Y	1 & 2
G-9	GORDON, W. E. "A Theory on Radar Reflections From the Lower Atmosphere." Proc. IRE. 1949. Vol. 37, p. 41-43.	U	Y	5
G-10	GORELIK, A. G., and CHERNIKOV, A. A. "Measuring Source Velocities for Reflections From a 'Clear' Sky." Trans. (Trudy) Third All-Union Radio-Meteorological Conference. April 1966. p.168-175.	U	Y	2
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